Cognitive Task Analysis: Analyzing the Cognition of Gameplay and Game Design

I/ITSEC 2013, Orlando, FL

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Overarching Goal

- **To better understand how COTs videogames can be leveraged for cognitive skills development**
  - Explore and validate design assumptions about specific games
  - Understand the cognitive and knowledge requirements to successfully play an immersive puzzle logic game

Background

- Prior research used Portal 2 as an intervention for enhancing cognitive adaptability (CA)
- Specific features were determined that was hypothesized would enhance CA
- Portal 2 was chosen based on a feature analysis including genre type, observed features, and player interviews
- Empirical validation of CA design features did not occur
- To validate if, where, how CA features occurred within the game, it was decided to use a cognitive task analysis

Cognitive Task Analysis (CTA)

- **Technique to capture and model behavioral and cognitive processes/activities for accomplishing a task at expert-level**
  - decision-making processes
  - recognizing and responding to critical cues/environmental conditions
  - utilizing tools
  - performing sub-tasks
  - analyzing and altering one's own performance
- **Commonly used by industry and research professionals**
  - Human computer interaction, instructional system design
  - Developing :
    - Intelligent/Cognitive Tutors
    - Decision Support Systems
  - Roots in cognitive science

Applying CTA to Video Games

- **Need to understand empirically:**
  - Design of game
  - How game design interacts with player cognition
- **Using CTA to map and model cognition and interaction within video game play is novel to the literature.**
- **Researching methods for applying CTA to video game analysis**

Lens of Analysis

- **Adaptability**
  - Ability to use existing knowledge to create innovative problem solutions; repeatedly trying new/different strategies while reflecting on actions and incorporating feedback
  - Identified by U.S. DoD, DoL, DoEd as an important metacompetency
  - Scale of macro to micro
    - Macro: adaptive stance, operational adaptability
    - Mid: individual adaptive behavior
    - Micro: micro-momentary cognitive processes, i.e., cognitive adaptability

Lens of Analysis

- **Cognitive Adaptability**
  - Micro (cognitive) Level
  - Components
    - Cognitive Openness/Creativity
    - Focused Attention
    - Cognitive Flexibility/ Metacognition
    - Critical Thinking & Problem-Solving

Lens of Analysis

5 Features for CA

- Unstated/Implicit Rules
- Unstated/Implicit Shifting of Rule Sets
- Dynamic Shifting Environments
- Open-Ended Gameplay
- Implicit Reinforcement for Individual Actions/ Choices to Achieve Final Goal

Research Goals

- **Develop protocol for performing cognitive task analysis on expert video gameplay**
- **Pinpoint how and where design tenets for cognitive adaptability are applied in Portal 2 and what types of decision-making and cognitive processing occurs as a result**
- **Map progression of cognitive load through gameplay of Portal 2**

Protocol: CTA & Video Games

Part I: Preliminary Analysis/Lexicon Development

- Establish vocabulary of game (names for features, tools, obstacles, etc)
- Game structure analysis: break game down into measurable units based on narrative structure

Features Provided By Steam

1. Pedestal Button
2. Button
3. Cube Button
4. Sphere Button
5. Weighted Cube
6. Companion Cube
7. Edgeless Safety Cube
8. Franken Cube
9. Tractor Beam
10. Faith Plate
11. Light Bridge
12. Stairs
13. Fizzler
14. Glass
15. Piston Platform
16. Track Platform
17. Laser Emitter
18. Laser Catcher
19. Laser Relay
20. Reflection Cube
21. Glass Panel
22. Angle Panel
23. Flip Panel
24. Observation Room
25. Laser Field
26. Turret
27. Deadly Goo
28. Light Strip
29. Bounce Gel
30. Speed Gel
31. Conversion Gel

Additional Vocabulary

Physical Features:
Water
Tilted Platforms
Beams
Ledges
Portal Tiles
Non-Portal Tiles
Elevator Tube
Stairs

Portal Items:
Portal Gun
Red Portal Hole
Blue Portal Hole

Distracter Objects:
Cans
Radio
Misc. Refuse

Misc:
PAL-esque Robot
Computerized Antagonist
Potato

Protocol: CTA & Video Games

Part 2: Focused Knowledge Elicitation

- Level-by-level:
  - *Please play through this level, completing the necessary steps to achieve the final objective. As you do, try to speak aloud as much as possible, narrating both your thought process (including what decisions you are making and what options you are considering) and the sequences of actions you take as you take them. As you play, please survey the areas you are in and describe your expectations in terms of how you will have to interact with the room in order to achieve your objective.*
- Gameplay recorded on FRAPS with audio plus simultaneous .wav file recordings.

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Part 2: Focused Knowledge Elicitation

- Subject and researcher review FRAPS gameplay for the following information about each level:
  - Affordances
  - Requisite Knowledge
  - Micro-Puzzles Present
  - Mechanical Steps Required
  - Cognitive Steps Required
  - Audio and Visual Cues

Example FRAPS: Ch. 1, Level 3

Cognitive Task Analysis

Chapter 1, Level 1

Affordances

Cube
Button
Door
Portal
Pedestal Button
Dotted Lines
Colors of Lines (yellow = active portal, blue = inactive portal)

Requisite Knowledge

Understand cube-button-door interaction
Understand function of pedestal button (to open door)
- Understand that pedestals have special specificity to portal activation
- Understand that only one pedestal/ portal can be active at a time

Understand relationship between blue portals and orange portals

Audio and Visual Cues

Door opening (A/V)
Sign with # of level, picture of cube and floor button (V)
Unidentified sounds when main room comes into view (A)
Sound of OP appearing upon entering room (followed by visual) (A/V)
Blue dotted line turns to yellow when pedestal button is pushed and makes sound, followed by BP appearing (A/V)
Visual of self through portal (V)
Dotted line and cube change color when cube is placed on floor button (V)
Voiceover when final door is opened (A)

Manual Steps Required

Push right pedestal button to create blue portal (BP)
Walk through orange portal (OP), come out BP
Pick up cube
Walk back through BP and out OP
Press left pedestal button to change BP location
Walk through OP and out BP with cube
Drop cube on button to open door
Walk through BP and out OP
Press center pedestal to change BP location

Micro-Puzzles Present

"It's not a puzzle until it becomes a problem."

Pedestal-Portal Interaction
Pedestal-Portal Spatial Specificity
Pedestal Button Sequence
Cube-Button-Door Interaction
Portal-to-Portal Relationship

Cognitive Steps Required

Decide on the order of pedestal/portal activation
- To get self to box
- To get box to button
- To get self to door

Induce constituative and operative rules as well as requisite knowledge

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Part 2: Focused Knowledge Elicitation

- Reviewing FRAPS gameplay a second time, identify presence or absence of design characteristics in question

Design for Cognitive Adaptability Rubric

Features 1 & 2: Implicit Rule Sets, Implicit Shifting of Rules

Rules	Description	Implicit or Explicit?	New or Altered Rule?	If yes, indicative of environmental change?
Constituative				
Operational				
Conduct				

Feature 4: Implicit Reinforcement for Individual Actions to Achieve Goal

Initial Expectations	**How Experience Differed from and/or Challenged Expectations**	**Explicit or Implicit Reinforcement?**

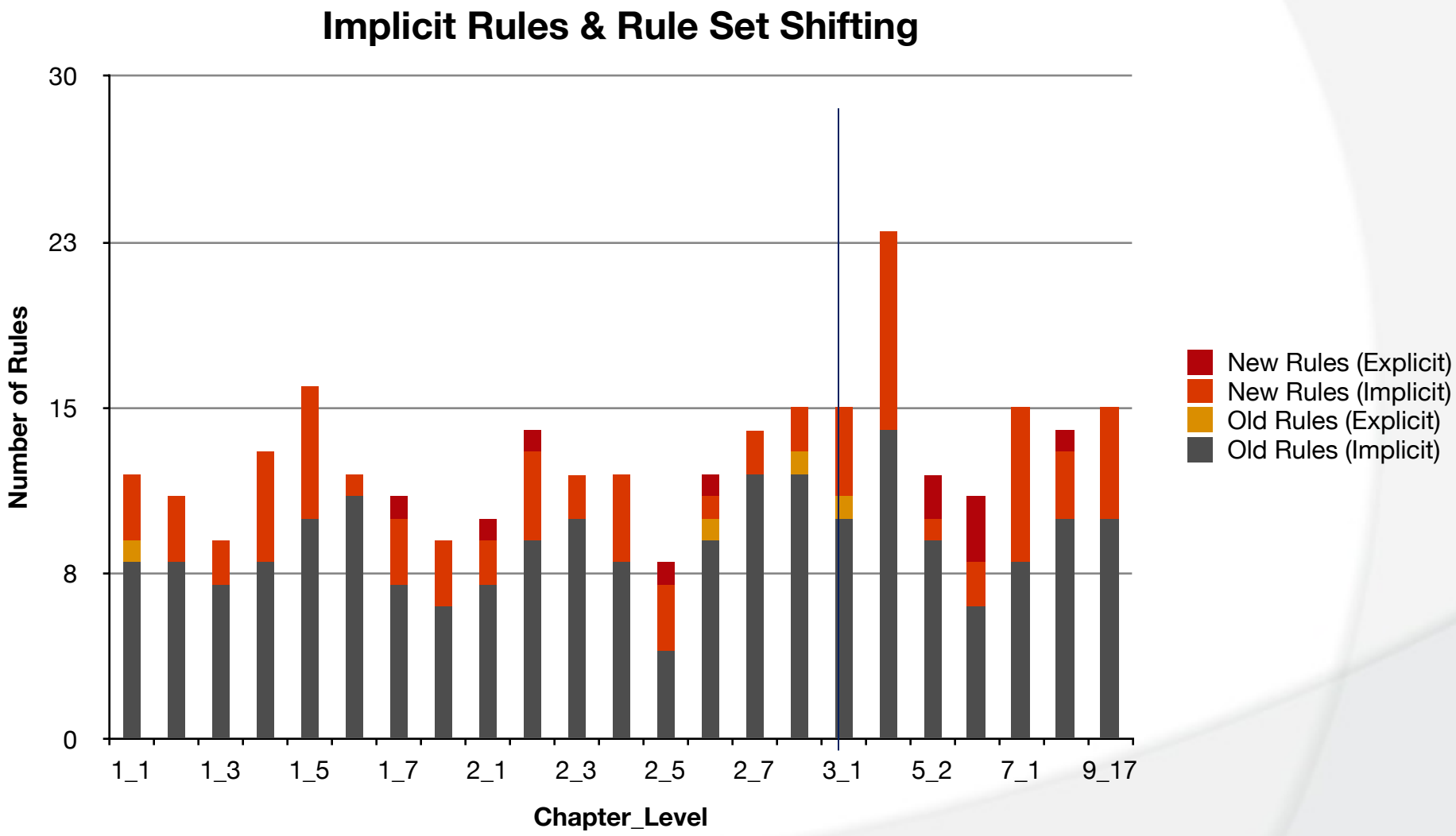
Features 3: Dynamic, Shifting Environments

Environmental Changes From Task Immediately Prior (please list)	Result of or cause of rule change? (Y/N)	Pure surface/ environmental change with no bearing on the rules (constituative, operational, conduct)? (Y/N)

Feature 5: Open-Endedness

Ways in Which Gameplay Was Open-Ended	**Ways in Which Gameplay Was Constrained**

Preliminary Results



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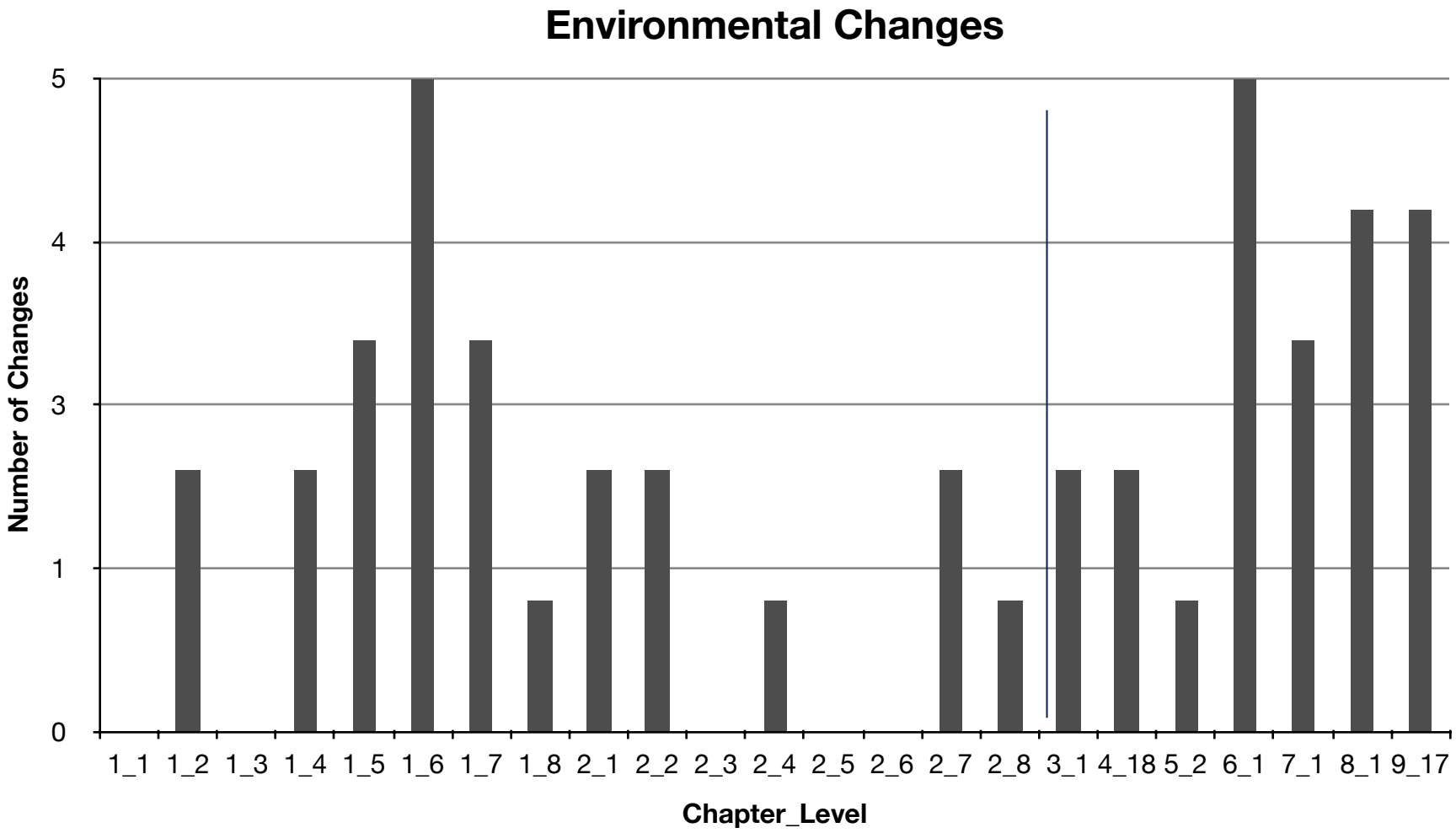

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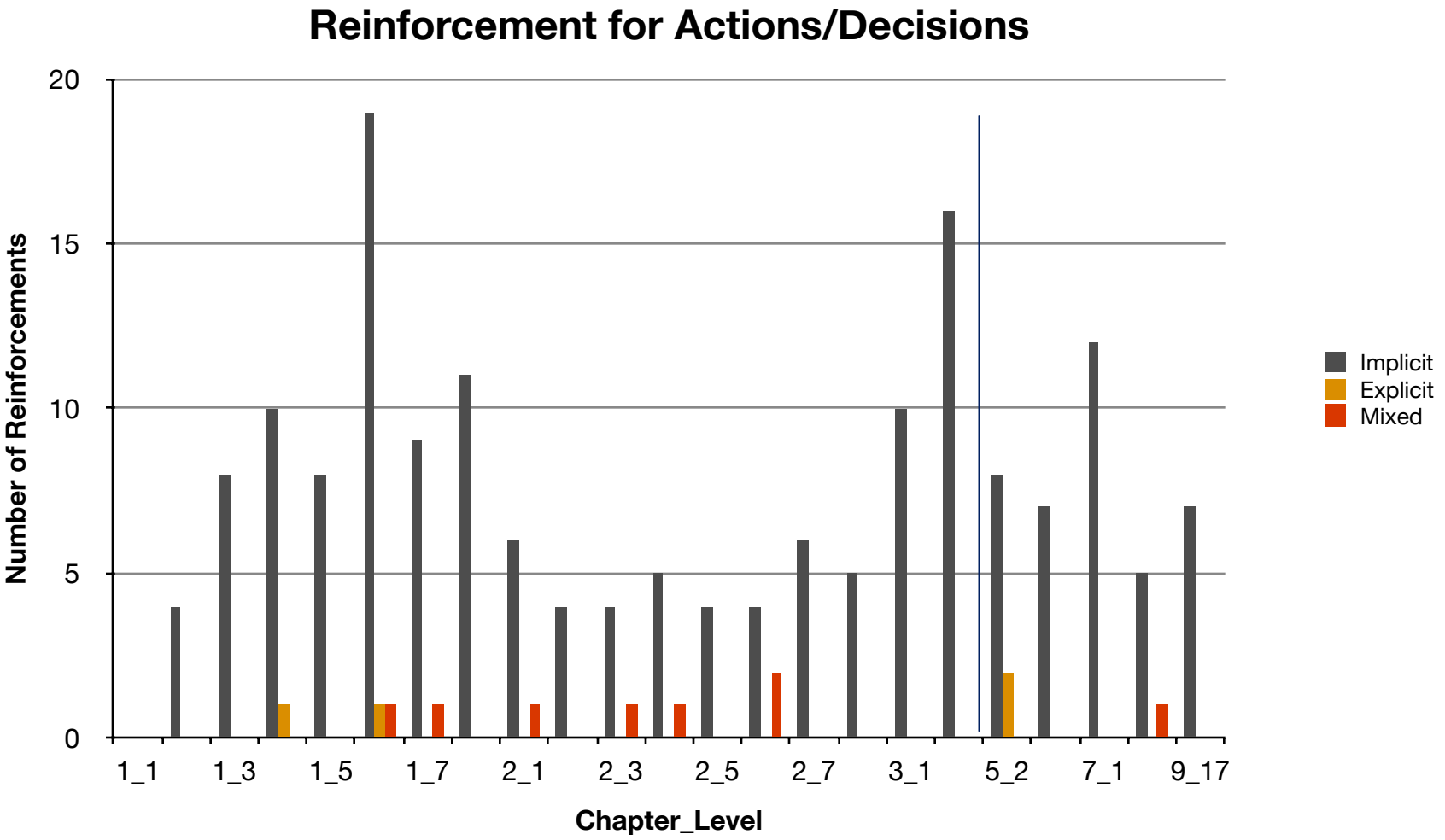
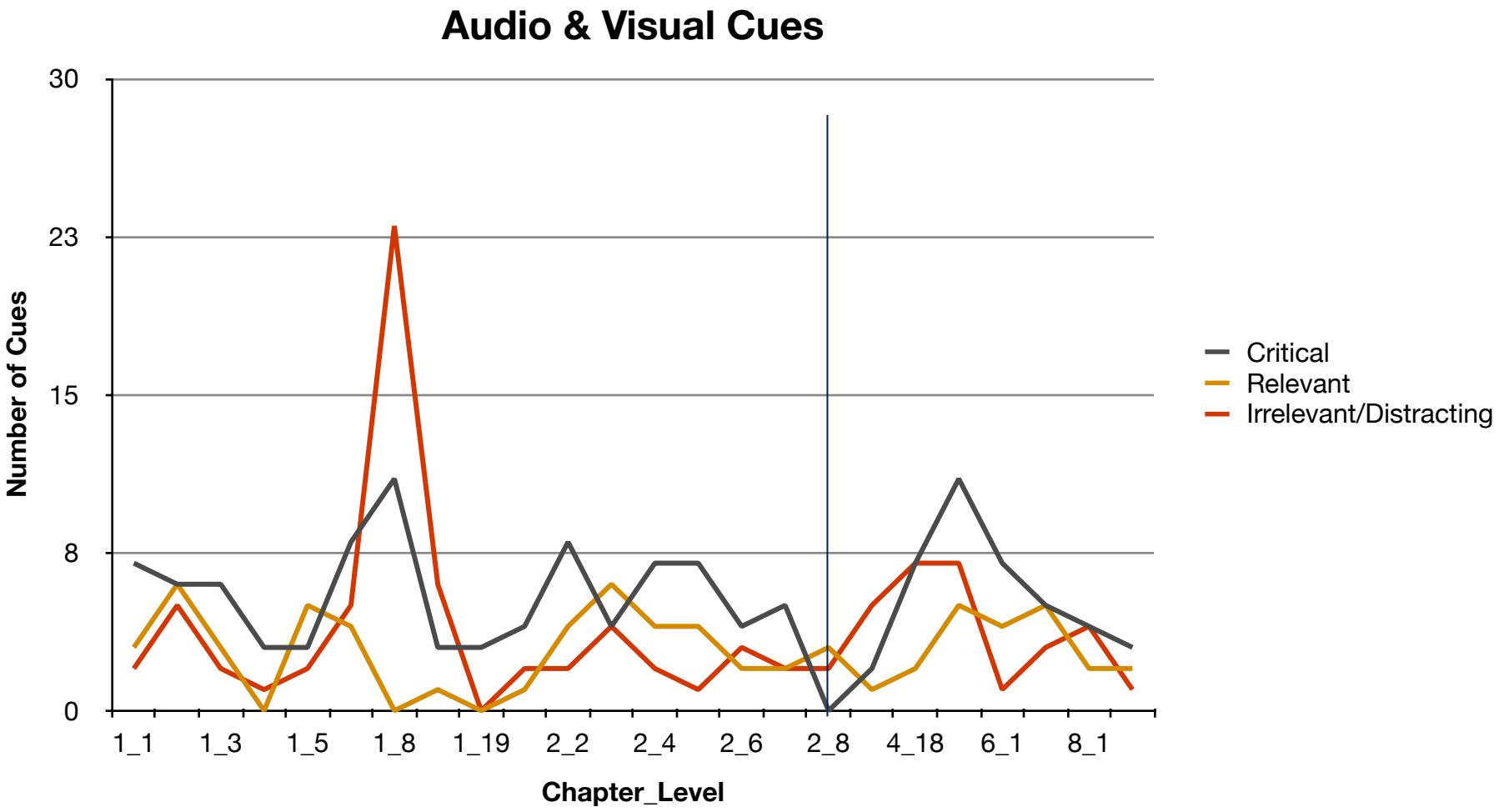


Preliminary Results

Instance of Open-Endedness	Count in Sampled Levels
Time unconstrained	22
Choice of portal-shooting location	14
Multiple ways to accomplish task	19
General	1
of moving box	5
by utilizing portal sequencing and environmental features	2
of moving laser acceptor via reflection cube placement	3
of transporting self/ objects	1
of retrieving defective turrets	1
of/while protecting self from avoiding bullets	1

Instance of Open-Endedness	Count in Sampled Levels
via portal/paint placement	2
via variable distances/speeds that can be used successfully with paint	1
via multiple jumping-off points/heights that can provide necessary momentum for task	1
via varied choices of box-turret hybrids to interact with	1
Freedom of movement/access to different spaces	22
Multiple ways to gain access to spaces/rooms	2
Control placement of both orange and blue portals	8
Player has some tools and opportunity to use tools that are not necessary to solve puzzle (i.e., portals)	1

Preliminary Results



Progress to Date

- **Protocol developed for CTA on video gameplay that encompasses cognitive, mechanical, and design elements**
- **Analysis shows modulating but persistent presence of all five cognitive adaptability design characteristics throughout Portal 2**
- **Indication of varying information processing/ filtering and executive function requirements throughout game**

Future Analysis

- Collect full data set on all levels
- Mapping the transition of micro-puzzles to tool sets/prerequisite knowledge
- Mapping the cognitive load evolution throughout game
- Critical path analysis
- Validate A/V cue level of relevance with subjects